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100 GeV PION INTERACTIONS IN PHOTOGRAPHIC EMULSION (A PARASITIC EXPERIMENT)

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Abstract

An experiment is proposed to expose a stack of photographic emulsion to the high energy, high resolution 100 GeV pion beam to study the interactions of 100 GeV pions with emulsion nuclei. The primary emphasis of this investigation will be to make a detailed comparison with the data already obtained from the interactions of 20,60 and 200 (mean energy of a cosmic ray sample) GeV pion interactions in emulsion. In obtaining the data for this comparison the data obtained will also be used to study the methods of energy estimation commonly used in analyzing the interactions of the secondaries resulting from primary interactions, the apparent forward asymmetry observed in pion-proton interactions in the cm system, the contribution of secondary nuclear cascading to multiplicities in high energy interactions with emulsion nuclei, coherent particle production, secondary particle multiplicity, and to determine the interaction mean free path.

The proposed exposure will require only a beam monitor to determine an exposure of approximately 5×10^5 pions/cm^2 over an emulsion target area of 100 cm^2. The experiment will make minimal use of the peripheral facilities of the National Accelerator Laboratory (NAL) and a very limited use of the beam to obtain the required intensity. This experiment can be run as a parasitic experiment to another pion experiment. A short down time in another pion experiment would be sufficient to obtain the proposed exposure. One can be reasonably sure that the entire procedure for obtaining the exposure will require less than half a day, depending on the precise location of the pion beam in the experimental area.

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Physics Justification

An experiment is proposed to expose a stack of photographic emulsion to the high energy, high resolution 100 GeV pion beam to study the interactions of 100 GeV pions with emulsion nuclei. An exposure of 5×10^5 pions/cm^2 on an emulsion target would allow the accumulation of a considerable amount of information about the interactions of 100 GeV pions with emulsion nuclei, which data can be obtained after development and scanning of the emulsion pellicles.

An enumeration of the areas in which the analysis of the pion interactions in the emulsion can lead to useful physics is given below (a more detailed discussion of these areas will follow):

1. A comparison of 100 GeV pion interactions with other pion data, accumulated by this experimenter and associates, at 20, 60 and 200 GeV in photographic emulsion.
2. A study of the methods of energy estimation, as determined from the angular distribution of the secondary particles from the pion interactions.
3. An investigation into the apparent forward asymmetry of the angular distribution of the secondary particles from the pion interactions.
4. Investigation of the contribution of secondary nuclear cascading to multiplicities in high energy interactions with emulsion nuclei.
5. A study of coherent production of particles and their cross sections.
6. Determination of the interaction mean free path in emulsion, as well as the elastic and inelastic cross sections with free and quasi-free protons in the emulsion.

Recently, there has been considerable emphasis into the comparison at various energies of the various features of the interactions of pions with emulsion nuclei. A collaboration has developed between this experimenter at Louisiana State University (LSU) and associates at the Institute of Nuclear Research (INR) at Krakow in which we are making a detailed comparison of pion interactions at 20, 60 and 200 GeV in emulsion. The pion data at 200 GeV[1] is the mean energy of a sample of pion secondaries from primary cosmic ray fragmentations. The energy spectrum of these pions is rather broad and the statistics are limited, while the data accumulated by this experimenter at LSU with 20 GeV[2] pions and the data of the INR in Krakow with 60 GeV[3] pions (obtained at Serpukhov) are quite detailed and extensive. A preliminary comparison[4] of these pion interactions has been made and a more complete comparison is in preparation; however, the limited statistics and broad energy range of the group with a mean energy of 200 GeV has limited the comparison and the extrapolation to higher energies.

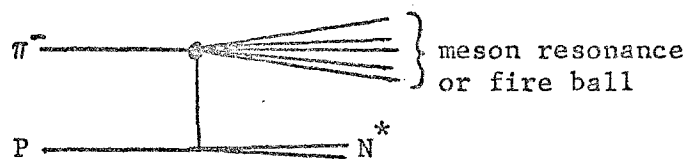
After the exposure and the development of the emulsions, a line scan will be made from which one will obtain the interaction mean free path and from which one will be able to determine the elastic and inelastic cross sections with free and quasi-free protons in the emulsion.

A preliminary comparison will be made of multiplicity trends with energy, secondary nuclear cascading in emulsion nuclei and coherent production of particles and their cross section based on this preliminary line scan in the emulsion. The coherent production[5] of particles by 60 GeV pions has been investigated and an analysis has begun at 20 GeV by this experimenter. It appears that the cross section for

interactions with three and five secondary pions increases with energy. A possibility of the further increase of this cross section has been suggested by the Krakow group[6] on the basis of several coherent interactions of cosmic ray pions at the mean energy of 200 GeV.

The analysis of the pion interactions, including secondary multiplicity, evaporation multiplicity and angular distributions will allow a detailed comparison with data already accumulated in the interactions of pions at 20, 60 and 200 GeV with emulsion nuclei. This will allow a comprehensive study of the energy dependence of the features of the interactions, as all of the prior data at 20, 60 and 200 GeV are available to this experimenter.

A study will be made into the apparent, forward asymmetry of the secondaries from pion-nucleon interactions which has become evident in the comparison paper.[4] This asymmetry is supported by 16 GeV,[7] 30 GeV[8] and 250 GeV[9] proton-proton interactions. It is of interest to see if the pion-nucleon asymmetry is analogous to the proton-proton asymmetry or if a physical process such as



exists, which causes the pion-proton interactions to be asymmetric in the forward direction. A recent Monte Carlo calculation using 60 GeV pions has been made to see if this asymmetry is due to the velocity approximation which is made in transforming laboratory values to center of mass values. Preliminary results indicate that this

velocity approximation is not the cause of this forward asymmetry.

Measurements will be made on the secondaries of the pion interactions to study the methods of energy estimation as determined from the angular distribution of the secondary particles. Again, extensive comparisons will be made with the 20, 60 and 200 GeV data. A summary of these methods for the case of 20 GeV pion interactions appears in the paper by E. R. Goza et al.[2] This study has indicated that the method of E-charge is clearly superior to the other methods; however, it is not clear that this method will be the most useful at higher energies. The 100 GeV pion data, coupled with the 20, 60 and 200 GeV data will allow a better comparison of the methods of energy determination in photographic emulsion.

This experimenter and associates at the University of Washington have recently presented a paper at the Cosmic Ray Conference in La Paz, with respect to the contribution of secondary nuclear cascading[10] in high energy interactions. This investigation used the results of 30 GeV[8] proton interactions and ICEF[11] results of proton interactions at cosmic ray energies. A similar study will be made using the 20, 60 and 200 GeV pion interactions already accumulated along with the use of the proposed 100 GeV pion experiment. The increased statistics of the 100 GeV pion exposure and narrow energy spectrum will make this investigation more meaningful.

It is very important, for some of the proposed comparison, that the data be analyzed and accumulated by those researchers who have analyzed the previous pion data and have complete results, which may be necessary for the comparison. This experimenter has collaborated with the emulsion group in Krakow, and has full use of their 60 and 200 GeV pion data as well as the data accumulated by this experimenter with 20 GeV pion and 30 GeV proton interactions in photographic emulsion.

Experimental Arrangement

There are a number of reasons why an emulsion exposure would be most appropriate during the early stages of beam operation:

1. The use of the facilities of the NAL would be very minimal, requiring only knowledge of the intensity and location of the pion beam.
2. The total time required in the experimental area would be from two to three hours, with actual beam exposure to the emulsion stack very short, requiring only 10 to 15 pulses of the primary beam for each of three emulsion stacks.
3. A considerable amount of data about the interactions of 100 GeV pions with emulsion nuclei can be accumulated in the emulsion target, without requiring any extensive experimental arrangements or peripheral equipment in the experimental area of the pion beam. No elaborate setups, counters, etc., will be required, just an alignment setup for the emulsion target in the experimental area.

Two or three pre-packaged stacks of emulsion will be placed in the pion beam in the experimental area for a period long enough to obtain an exposure to approximately 5×10^5 pions/cm^2 over an emulsion target area of 100 cm^2. The stacks must, of course, be precisely aligned with respect to the pion beam; consequently, one must have accurate alignment of the emulsion target in the experimental area.

If the precise location of the pion beam is not known, a simple arrangement of 500 micron emulsion plates can be used to make a suitable horizontal and vertical beam profile. The beam profile could be obtained in the morning with the primary emulsion stack exposure to take

place in the afternoon. The beam profile would require 10 to 15 pulses of the primary beam in order to make a satisfactory intensity and beam location determination.

Assuming the beam location and intensity are accurately known in the experimental area, the exposure of three stacks of emulsion pellicles will require only a very short exposure to the pion beam. For a typical intensity of 10^6 pions/10^{13} protons on target, one can obtain a suitable emulsion exposure with only 10 to 15 pulses of the primary beam at the above intensity. Certainly, this procedure will make minimal use of the pion beam and other NAL facilities, and can be accomplished in less than an afternoon. Once the emulsion stacks are aligned, the exposure can obviously be accomplished very quickly.

Apparatus

The proposed experiment will not require any apparatus other than a leveling arrangement for the precise alignment of the emulsion stack with the pion beam. However, it will be necessary to know the intensity of the pions on the emulsion target in the experimental area.

If the precise beam location and the pion intensity are not known, a simple arrangement of 50 micron emulsion plates can be used to make a satisfactory determination of the beam profile for the purposes of this experiment. This latter study would require the use of darkroom facilities for about one hour and a binocular microscope with overall magnification of about 250X for about the same period. (The experimenter can bring with him the necessary chemicals and a microscope if they are not available.) A vertical and horizontal beam profile can then be obtained for the subsequent emulsion exposure. This beam profile may also be useful to other experimenters.

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